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CHANGES IN BONE TISSUE UNDER CONDITIONS OF HYPOKINESIA AND IN CONNECTION WITH AGE

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Translation of "Zmini kistkovoi tkanini v umovakh hipokinezii ıa v zv'yazku z vikom", Fiziolohichnyy Zhurnal, vol. 19, No. 6, Nov-Dec 1973, pp 841-843

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16. Abstract

This article describes a study of bone substance under conditions of hypokinesia and with age.

Methodology used is presented.

It concludes that bone tissue, a highly dynamic structure, can change not only with age but also in a relatively short period of time.

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CHANGES IN BONE TISSUE UNDER CONDITIONS OF HYPOKINESIA AND IN CONNECTION WITH AGE

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In the process of phylogenesis bone tissue is formed as a protective adaptation which opposes the factors of gravitation and pressure [3]. It is natural that movement in the structure of the bone can be distinguished in hypokinesia. The effect of hypokinesia on the bone structure can be investigated not only in extreme situations, fixation of the position of the body and strict bed confinement, etc., but also in the process of human existence. It is a well-known fact that muscular activity decreases somewhat with age and that this develops conditions of hypodynamia. Therefore, regardless of how the hypokinesia conditions develop, in the final analysis it seems that the same problem must be solved, namely how the bone tissue resists changes in factors in the external environment.

Research Methodology

We used two methods of studying bone tissue: X-ray micrographs and X-ray structural analysis.

We used the X-ray micrograph method to study the optical density (degree) of the blackening of X-ray photographs made of five bones in nine young people aged 24 to 29. Measurements were made before and after hypokinesia (strict bed confinement for 16-37 days). The optical density of the X-ray films was studied by photometry, and the photometric results were automatically recorded in the form of curves. Comparison of the optical density of the roentgenograms of the bone tissue up to the hypokinesia condition and after it can be made according to the relative concentration of bone substance under these conditions.

The theoretical basis of the method of X-ray micrographs follows the law of intensification of X-rays [6].

The X-ray structural analysis method was used to investigate the bone tissue of 25 cadavers of practically healthy individuals who died from various injuries; their ages ran from 18 to 70.

The essence of X-ray crystal analysis [1, 2] consists of studying the structure of the crystalline matter with the aid of X-ray interference.

In the experimentation we used monochromatic X-ray radiation of copper by adapting a nickel filter. We studied areas of bone tissue of 3 X 5 X 30 mm, removed from the cortical layer of the diaphysis of femurs.

The bone tissue research was conducted with a URS-50-IM X-ray apparatus with a GUR-4 goniometric appliance on which the bone area was placed with respect to the narrow X-ray beam. The maximum interference was automatically recorded on graph paper with an automatic recording potentiometer.

Research Results

It was found, as a result of the X-ray micrograph research, that under conditions of hypokinesia (strict bed confinement) for 16-37 days, a drop in the density of the bone substance in the five bones occurred in some of the subjects while, on the other hand, it increased in the other subjects.

In analyzing the X-ray films it was even possible to visually discern that in individuals with a high initial density (up to the condition of hypokinesia), the concentration of bone matter was obviously reduced after hypokinesia; the degree of reduction increased over the period of observation; the picture of the bone matrix became thin and rarefied, an expansion of cavities between bone structures could be seen, and consequently all of the symptoms and properties of osteoporosis were observed.

On the other hand, in subjects with a relatively low initial bone density, the concentration of bone matter increased in association with comminution of the bone matrix and a reduction in openings between bone structures.

The same regularity appeared in the photometry of the X-ray films of the five bones. If the maximal density of the bone tissue at the start of the research in some subjects is taken to be 100 units, the minimal initial density in other subjects corresponds to 72.5-82.5 such units.

In subjects with a high initial bone density (close to 100 units) a reduction was observed after 16 days to 80-85 units; after 37 days of research the density dropped to 70.5-80.0 units. At the same time, in individuals with an initial bone tissue density of 72.5-82.5 units, the concentration of bone matter increased to 90 units after 16 days under conditions of hypokinesia, and reached 90-95 units in 37 days. Therefore in subjects with a high initial bone density, a reduction in the concentration of bone matter was observed, averaging 20-25%, during the period of observation (37 days). Bone matter density in a low initial concentration increased an average of 20%. Thus the reaction to the state of hypokinesia is not uniform in different individuals, and is quite often directly reversed.

Now it is necessary to say something about the mechanism of development of this reaction of an organism on the state of bone tissue under conditions of hypokinesia. Obviously further research in this direction will aid in explaining the essential points of this phenomenon.

The research conducted established that pronounced osteoporosis of the bone tissue can be found after a relatively short period of time under conditions of hypokinesia in practically healthy young individuals, although it usually develops only as a function of age. In the past it has been stated in the literature that osteoporosis begins in old age, and thus up to now

it had not been determined whether there was a change in the submicroscopic structure of the bone, especially its crystalline component--hydroxyapatite [3, 6], and the concentration and structure of the crystals which tangibly determine the strength of the bone. We used the X-ray structural analysis method to solve this problem.

The results of the X-ray structural analysis produced three interference maxima. The first maximum was observed at an angle of 26°, the second at 32° and the third at nearly 40°. The clearest was the first peak recorded, corresponding to a 26° angle, other recorded peaks being blurry (shown indistinctly). This type of X-ray crystallograph is typical of bone hydroxyapatite, according to data in the literature [6].

Some differences in the intensity of interference maxima and their expression are demonstrated when the roentgenograms (crystallograms) of hydroxyapatite from individuals of different ages are compared. This established the fact that the intensity of interference maxima increases somewhat to the age of 20-25. At this age there most often appear abrupt, high peaks in the X-ray crystallograms, and from 25 to 60 the intensity of the interference maxima remains almost constant. A reduction in the intensity of interference maxima appears in people over 60.

An analysis of the X-ray crystallograms obtained showed that the dimensions of the hydroxyapatite crystals change little with age.

Thus it was established that the stabilization of the crystalline structure of the hydroxyapatite, especially the formation of its crystals, is finished by the age of 20-25. From 25 to 60 the crystal lattice remains in a stable condition, but according to the X-ray structural analysis a

reduction in the hydroxyapatite density is recorded, which is confirmed by a reduction in the intensity of the interference maxima.

In conclusion it is necessary to state that the bone tissue, a highly dynamic structure, can change not only with age, but also in a relatively short period of time. A change in body position (state of hypokinesia) with respect to the gravitational field leads to essential disruption in bone (density) structure. These changes in the bone tissue of different individuals are not uniform. The reaction of the bone tissue to the conditions of hypodynamia is inadequate (contrary). It is obvious that these conclusions should be taken into consideration with respect to people intended for work associated with the condition of hypokinesia.

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